ESTIMATES OF DESERT TORTOISE POPULATION DENSITY ON THE 18-SQUARE MILE COMPLEX ONE CHARLIE AREA, EDWARDS AIR FORCE BASE, CALIFORNIA

Prepared For:

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1. INTRODUCTION

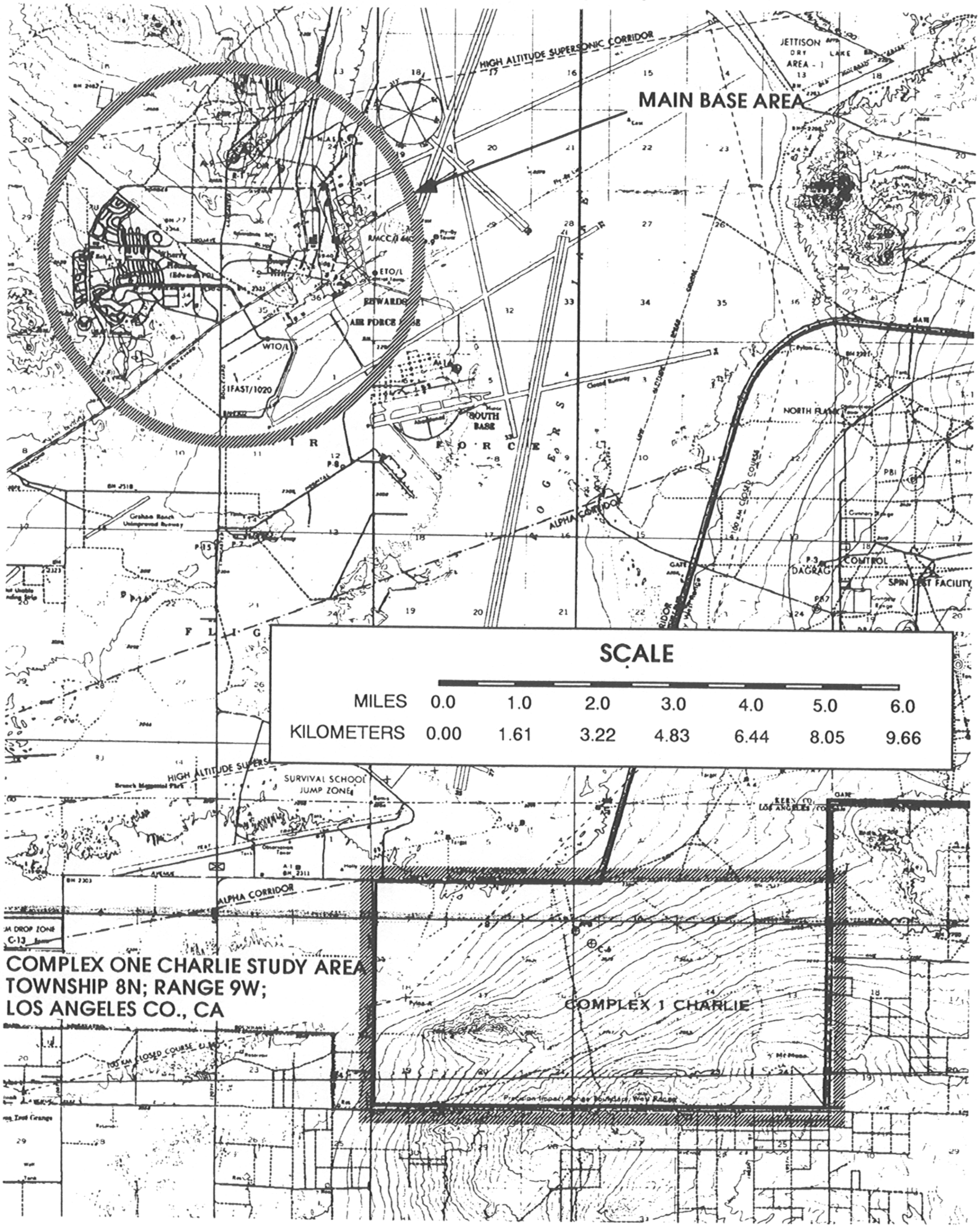
The desert tortoise (*Gopherus agassizii*) was listed as "threatened" by the U.S. Fish and Wildlife Service in April 1990 and thus has full protection under the Federal Endangered Species Act. The act requires that any action proposed by a federal agency that may affect a listed species be assessed for its impacts to that species.

This study was designed to estimate densities of desert tortoises on and adjacent to the proposed project site. Additionally, historical human impacts on the site were mapped and quantified.

2. STUDY AREA

The Complex One Charlie study area is an 18 square mile block of land on Edwards Air Force Base (EAFB; Figure 1). The north boundary of Complex One Charlie is approximately 1.21 kilometers south of the southern tip of Rogers dry lake. The study area is all located in Township 8 North, Range 9 West of Los Angeles County. It includes sections 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, and 24. The south boundary of Complex One Charlie is also the south boundary of EAFB property.

Figure 1. Complex One Charlie Study Area Vicinity Map

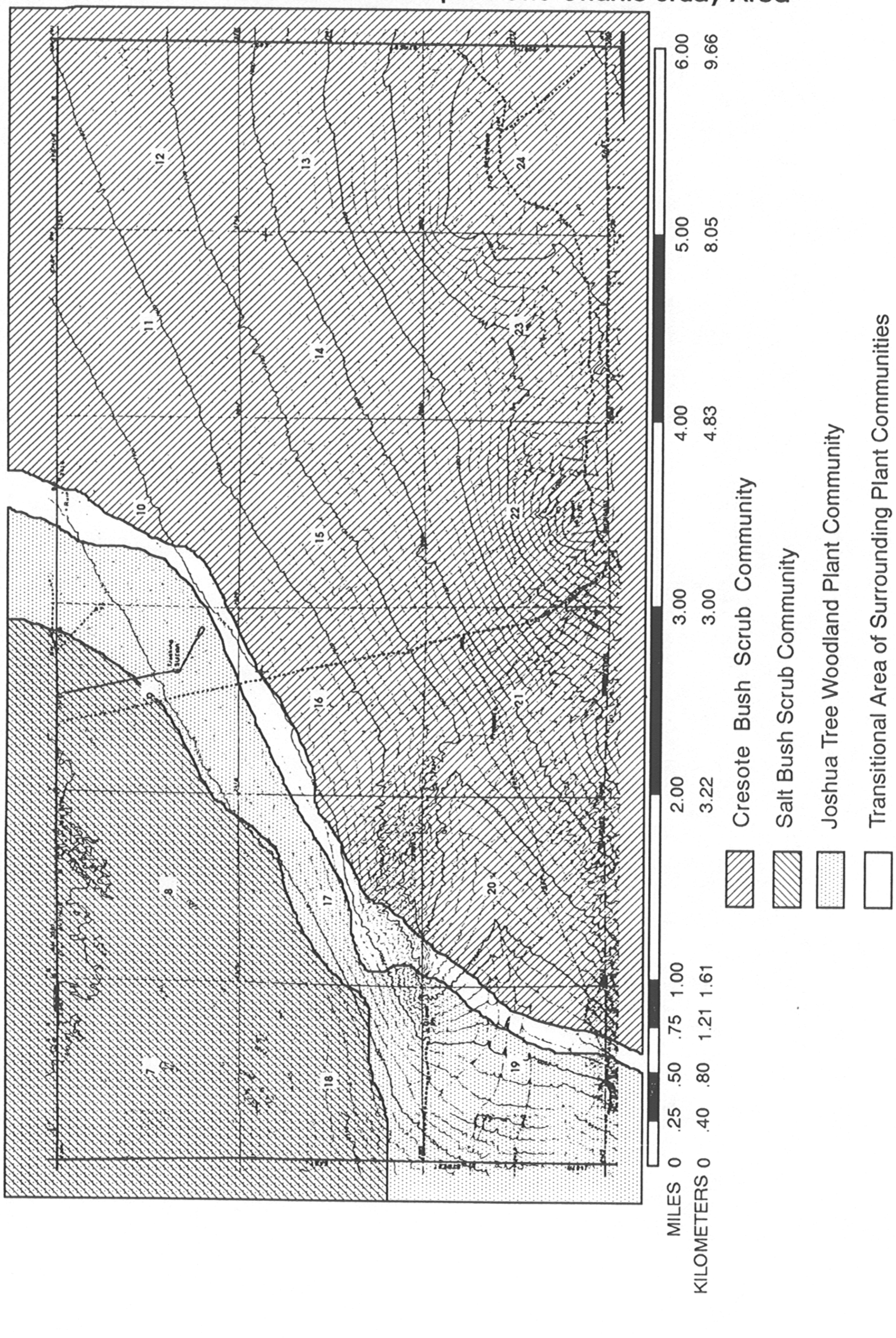


The study area currently has no human habitation. Evidence of historic human use includes several old homestead sites, concrete slabs, radar tracking sites, aircraft pylons, a dump site, and sheep scat. Evidence of current human use includes radar tracking sites, off-highway vehicle (OHV) trails, a two-lane paved road along the western boundary of the study area and half of the northern boundary, lightly used unimproved roads along the east and south boundaries, and a few dirt roads and trails usually leading to old homestead sites or tracking facilities in the interior of the study area.

Elevations range from 701 to 967 meters (2300 to 3174 feet). The area is geomorphologically diverse. The northwestern area nearest Rogers Lake is a nearly flat floodplain that drains toward Rogers Lake. To the south, this transitions rapidly into bajada slopes. Moving up slope to the south, the area becomes hilly. A small valley with a large wash lies across these hills. In this wash area, the slope aspect becomes predominantly westerly along the wash drainage whereas most of the rest of the area slopes to the northwest. Moving to the southeast from the northwest corner, the geomorphology transitions from flats to a gentle bajada sloping to the northwest. Further to southeast, this bajada transitions into hills on the south boundary of the study area. The highest point, Mt. Mesa, is located in the southeastern-most section.

Three plant communities exist on the study area (Figure 2). The northwestern area nearest Rogers Lake is a saltbush scrub plant community consisting primarily of allscale (*Atriplex polycarpa*). As the elevation increases to the south and southeast, the plant community transitions to Joshua tree woodland composed of Joshua trees (*Yucca breviofolia*) and creosote bush (*Larrea tridentata*) in association with burrobush (*Ambrosia dumosa*). Joshua tree woodland was defined as an area composed of at least 100 Joshua trees per square mile. Further upslope into the hilly regions of the study area to the south and southeast, the plant community becomes creosote bush scrub (Munz, 1974) dominated by creosote bush in association with burrobush with relatively few Joshua trees.

Figure 2. Plant Communities on Complex One Charlie Study Area



3. METHODS

Since the purpose of this project was to estimate population density of desert tortoises in a large area (46.6 km^2), relative density transects were used as an analysis tool. No habitat altering action is proposed for the study area so a total coverage survey as recommended by the U.S. Fish and Wildlife Service (1990) was not required.

Relative density transects are a method of relating counts of desert tortoise sign, scat and burrows primarily, to population density of tortoises in an area (Berry and Nicholson; 1979, 1984). The number of sign in a known density area is counted and a relationship between sign counts and desert tortoise population is established. Identical counts at an unknown density area are made and the relationship established at the known density area can be used to roughly approximate the density of desert tortoises at the unknown area. The known density areas used are Bureau of Land Management desert tortoise population trend plots. About 16 of these one square mile plots are currently being monitored on a four-year rotational cycle using a 60-day mark-recapture census technique. The data generated from the census is then used in a population model for estimation of the total desert tortoise population density.

Each transect is an equilateral triangle, each leg 0.8 kilometers (0.5 mile long), totalling 2.41 kilometers (1.5 miles) in length. The transect width is 10 meters.

Gilbert Goodlett and Glenn Goodlett walked relative density belt-transects within the study area. Field work was commenced on July 8 and completed on July 30, 1991. Three transects were walked in each section yielding a total 54 transects or 130 transect-kilometers (81 transect-miles) walked on the study area (Figure 3). The planned transect site origin points were at the center of each section. The latitude and longitude of the center of each section were entered into a handheld LORAN navigation instrument so that each observer could navigate to the center of the section. In the field, we did not always start at the center of each section due to poor accessibility. Transects were spread evenly throughout the section even if access to the planned origin in the center of the section was difficult. The LORAN instrument was used to record the latitude and longitude of the origin of each transect. While these data are not used in this analysis, they may be useful if this information is later used in a Geographic Information System (GIS).

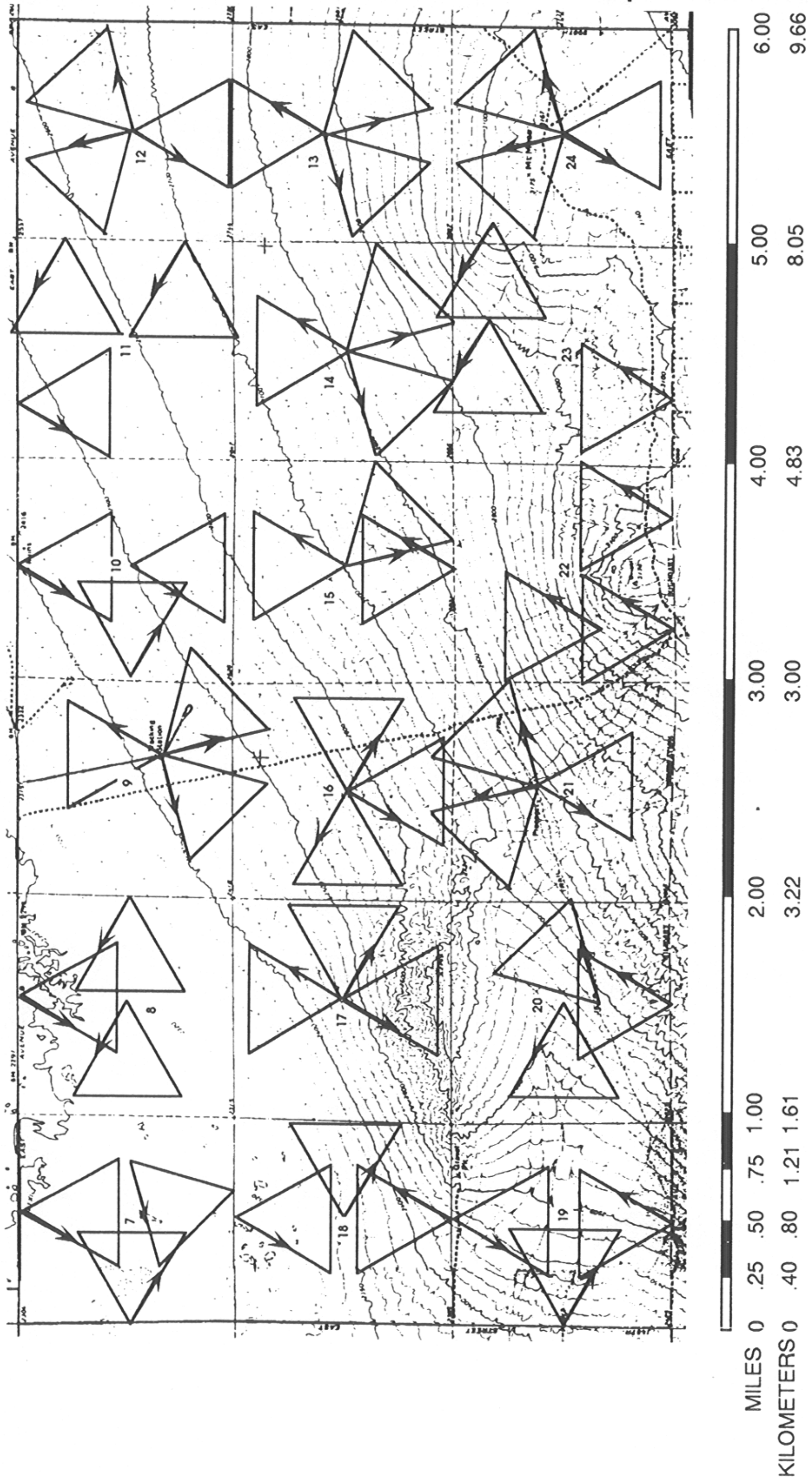
Data were recorded on standardized transect forms (Appendix 1). These data included general site description such as date of survey, time (in Pacific Standard Time), temperature (in ºC), percent cloud coverage, transect number, total sign, total corrected sign, geomorphology, dominant substrate, particle size range, dominant perennial plant species, number of perennial plant species, aspect, slope average in percent, and elevation (in feet). Locational data were also described including: topographic quadrangle name and scale, township, range, section, subdivision (the portion of the section in which the transect lies), county, latitude and longitude, individual paces per 1/2 mile (varies with observer), and a small map of the transect orientation with respect to the section.

Several categories of tortoise sign can be observed and are delineated on the transect form. These include: coversites (burrows usually), scats, live tortoises, shell remains, tracks, and courtship ground disturbances. The only items that were included in corrected sign counts (although they may be lumped together if indicative of a single tortoise) are burrows and scats. Shells are not included because calibrations are done on permanent study plots where shells have been removed during the study; hence there is no measure of the abundance of remains versus the density of tortoises. Tracks and courtship ground disturbances are highly dependent on both soil characteristics and the time of year. Live tortoise observations are related to weather conditions and the time of year. Sign not included in TCS is recorded to indicate the presence of tortoises if no corrected sign is seen.

Data on burrows and scats were recorded. For burrows, this included the pace count at which the sign was found, the length, width, height, and soil cover at entry of burrows (all in mm), the condition of the burrow, the location with respect to vegetational or topographic features, and the number of scat associated with the burrow. Conditions of burrows were ranked into the following categories: excellent - tortoise in burrow or evidence of recent use, good - burrow in good condition but no evidence of recent use, fair - burrow may be degrading, vegetation in mouth, and poor - burrow degraded significantly, may be partially collapsed but still usable by tortoises with some cleanup.

Scat data entered included size (using standard size-age classes), condition (either TY = this year or NTY = not this year), and location.

Figure 3. Location of Transect Sites on Complex One Charlie Study Area



Data on live tortoises and carcasses were recorded in the next section. This included type of report (L=live, S=shell), pace count, sex (1=female, 2=male, 3=unknown or too small to sex), size, location with respect to vegetational or topographic features, activity, condition, aging, and whether remains were associated with a *Neotoma* midden. Sizes were listed in millimeters maximum carapace length (MCL), or when the tortoise was partially hidden in a burrow or a shell was disarticulated, the standard size-age class definitions were used. These include: JV = juvenile (<100 mm MCL), IMM = immature (100 - 180 mm MCL), SA = subadult (180 - 208 mm MCL), AD = adult (> 208 mm MCL). Conditions included healthy, diseased, or unknown for live tortoises and inverted, upright, or disarticulated for shell remains. The "Aging" category was used for shell remains only. Remains were categorized in terms of time-since-death using keys (Berry and Woodman, 1984). The classes used included 1) dead < 1 yr, 2) dead 1 to 2 years, 3) dead 2 to 4 years, and 4) dead > 4 years.

The back of the form was used as a continuation of burrow and scat data, for recording tortoise track data, and for tallying human impacts observed on the transect. Track data included the pace count, location with respect to vegetational or topographic features, width of tracks (in mm or size-age class), sex (the longer tails of males may leave a distinctive drag mark), age (recent or old), and courtship ring lengths and widths in millimeters.

Human impacts are logged in the last section of the form. Categories used included the following:

A. Number of paved roads.
B. Number of dirt roads.
C. Number of vehicle trails where a vehicle trail is defined as a "non-official" road that has been used by multiple vehicles.
D. Number of vehicle tracks on or off of a road or trail.
E. Number of refuse items where a refuse item is defined as any non-native item of human origin or a conglomeration of individual items too numerous to individually count in one place. Items such as road signs that are obviously intended to be there were not included. Special note was made of unusual or unusually significant refuse items.
F. Number of targets used for shooting. This category was extended to include a count of spent ammunition casings, also.
G. Number of shooting areas where shooting areas were defined as areas showing a high concentration of repetitive shooting activity.
H. Number of mining affected disturbances including assessment sites, mine shafts, etc.
I. Number of campsites.
J. Number of sheep affected areas including scat, bedding areas, and watering areas.
K. Number of cattle affected areas. None are located on Complex One Charlie.

L. Number of wild horse or burro affected areas. None are located on Complex One Charlie.
M. Tally of evidence of wild or domestic dog activity. None are located on Complex One Charlie.
N. Fencelines, and fence posts counted on the transect.
O. Utility lines and towers.
P. A count of areas of denuded habitat where no native perennial vegetation remains.
Q. A count of areas of partially denuded habitat where little native perennial vegetation remains.
R. A record of the number of old buildings encountered on the transect.
S. Number of other surface disturbing activities where not delineated above. These were described.

A map consisting of three parallel lines, each representing a leg of the transect, was used for mapping human impacts on the form. The letter that refers to the human impact category is used to represent that category on the map. Pace counts were also written on the map.

Immediately after completion of field work at Complex One Charlie, calibration transects were walked by both observers on three Bureau of Land Management (BLM) desert tortoise population trend plots. The plots used were Lucerne Valley, Kramer Hills, and Fremont Peak. These plots were selected based on 1) similarities of habitat to the Complex One Charlie study area, 2) obtaining a range of tortoise densities for correlation, 3) proximity to the study site.

Six calibration sets were walked on each study site yielding a total of 36 transects for both observers. These transects were oriented in standard directions of N, W, E, S, NW, and SE.

4. RESULTS

4.1. Calibration

Calibration transects were walked by each observer at each of three 1.0 mi^2 (2.6 km^2) BLM permanent desert tortoise study plots. These plots have been censused using a 60-day mark-recapture method. Since observers are not able to find all animals, a population model is used to estimate the total population. Because smaller animals have a lower observability, a model that considers the variation in observability with size-age class was used. The BLM used the Lincoln Stratified Index (Overton, 1971).

The three plots selected for calibration were censused in different years; Lucerne Valley in 1990, Kramer Hills in 1991, and Fremont Peak in 1989 (Table 1). The population estimate for Kramer Hills has not yet been published and was provided upon request by Dr. Kristin Berry (personal communication) of the BLM.

Table 1. Estimated population density and confidence intervals from three BLM permanent study plots

Calibration Site	Estimated Population (tortoises/square mile)	Confidence Limits at 95%	Reference
Lucerne Valley	82	56-120	Berry 1990
Kramer Hills	66	43-100	Unpublished
Fremont Peak	32	14-50	Berry, 1990

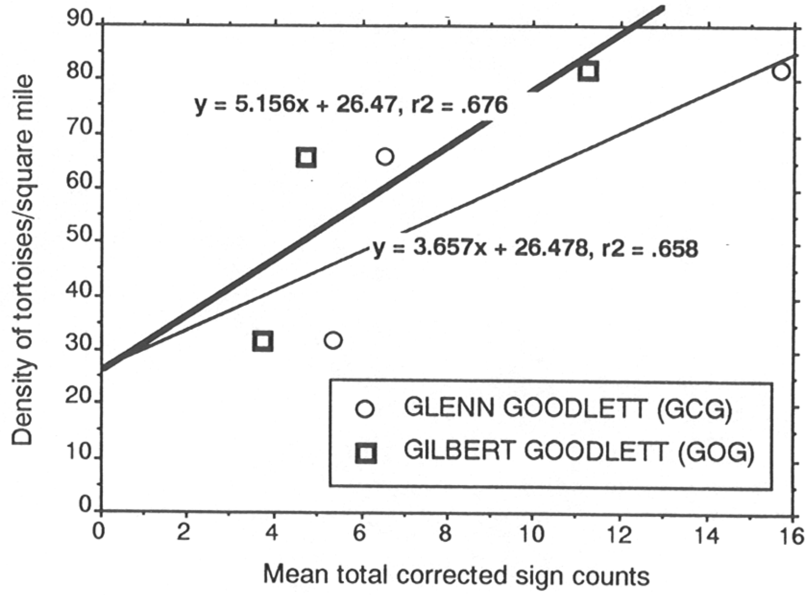
Calibration data were obtained from BLM study plots for both observers along with population data for these locations (Table 2). Original calibration data sheets are contained in Appendix 2.

Table 2. Calibration data and estimated desert tortoise density from three BLM permanent study plots

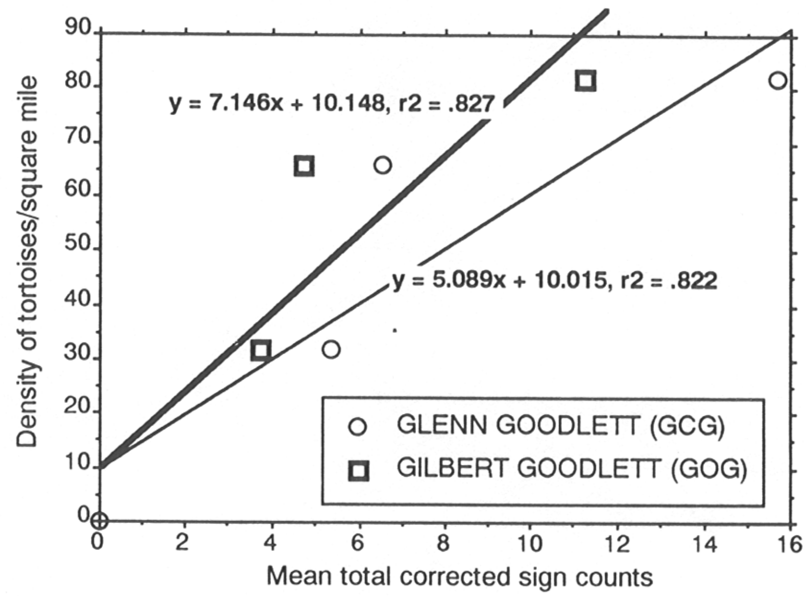
Site	Transect Orientation	GCG[1] Total Corrected Sign	GOG[2] Total Corrected Sign	GCG Average Sign Count for Plot	GOG Average Sign Count for Plot	Projected tortoise density
Lucerne Valley	N	24	20			
Lucerne Valley	W	12	5			
Lucerne Valley	S	13	7			
Lucerne Valley	E	14	11			
Lucerne Valley	NW	17	10			
Lucerne Valley	SE	14	14	15.67	11.17	82
Kramer Hills	N	2	5			
Kramer Hills	W	10	5			
Kramer Hills	S	12	7			
Kramer Hills	E	5	3			
Kramer Hills	NW	7	5			
Kramer Hills	SE	3	3	6.50	4.67	66
Fremont Peak	N	12	6			
Fremont Peak	W	3	5			
Fremont Peak	S	9	4			
Fremont Peak	E	3	3			
Fremont Peak	NW	3	2			
Fremont Peak	SE	2	2	5.33	3.67	32
Totals		165	117			

1. G C G = Glenn Goodlett
2. G O G = Gilbert Goodlett

These data were analyzed using a linear regression for each observer by plotting the estimated density of tortoises vs. each observer's sign counts. The regression (shown at right) using these three data points resulted in poor correlation for each observer (r^2 = .676 and .658).



In this figure, the assumed point of 0,0 has been added to the plot. It is assumed that when the density of tortoises is zero, no sign will be observed. This is a typical assumption of this analysis. However, the regression line was not forced through 0,0. The new correlation coefficients (.827 and .822) indicated a good curve fit. This calibration chart and resulting equations were the ones used for data analysis.



4.2. Estimated densities

Table 3 shows the sign counts for the Complex One Charlie area along with the predicted population density for each transect. Estimated densities were calculated using regression equations for each transect. A different equation was used for each observer. This yielded the projected desert tortoise population densities for each section. The predicted density was averaged for the three transects walked in each section (Table 2).

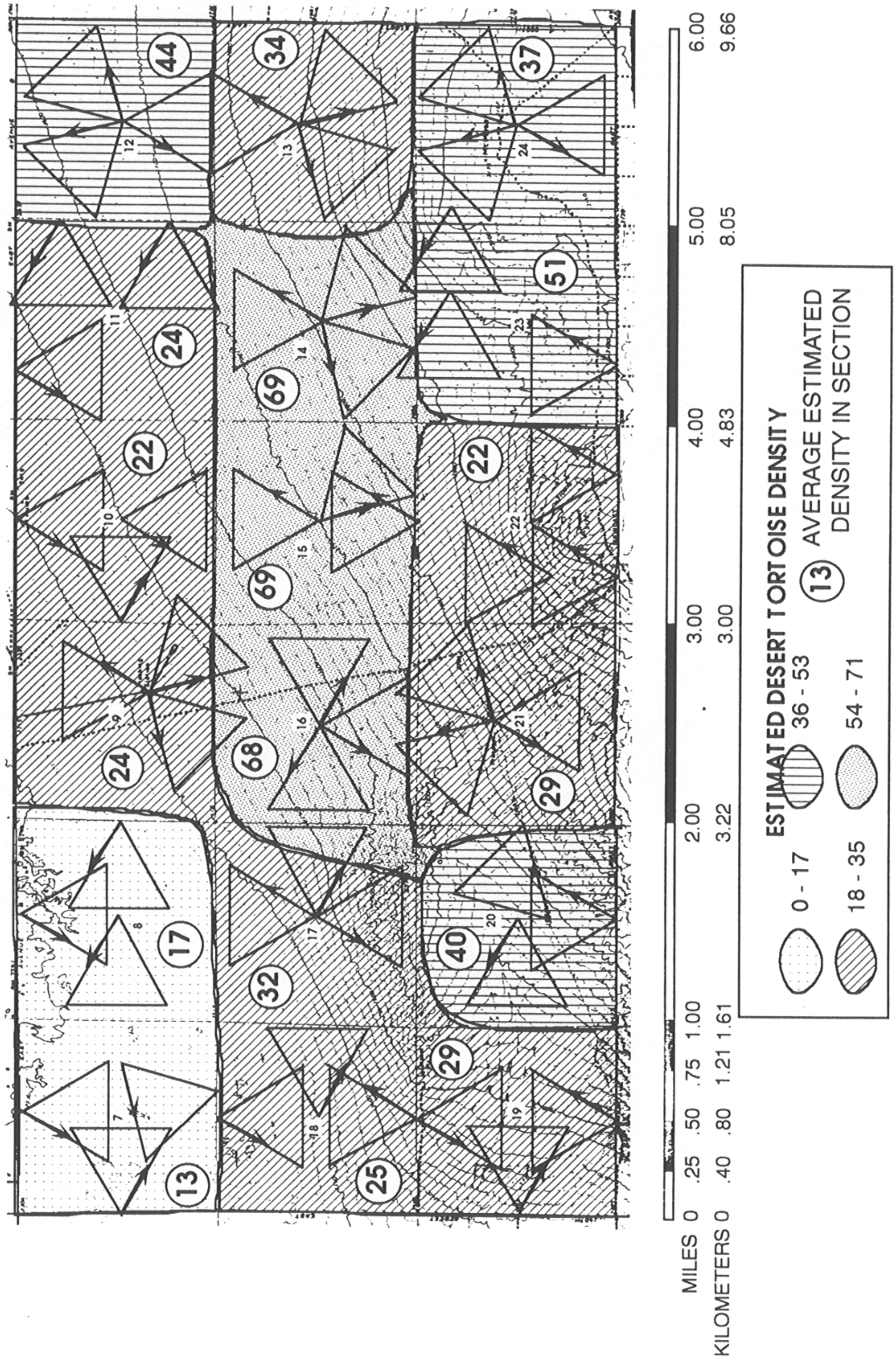
Table 3. Total Sign, total corrected sign, and estimated desert tortoise density/square mile at 18-square mile Complex One Charlie study area

Section	Transect number	Total Sign	Total Corrected Sign	Observer	Estimated Density from Regression Analysis	Mean for each section
7	1	0	0	GOG	10	
7	2	1	1	GOG	17	
7	3	1	0	GOG	10	13
8	1	0	0	GCG	10	
8	2	4	3	GCG	25	
8	3	1	1	GCG	15	17
9	1	2	2	GOG	24	
9	2	3	3	GOG	32	
9	3	1	1	GOG	17	24
10	1	10	7	GCG	46	
10	2	2	0	GCG	10	
10	3	0	0	GCG	10	22
11	1	3	3	GOG	32	
11	2	2	1	GOG	17	
11	3	2	2	GOG	24	24
12	1	12	6	GCG	41	
12	2	7	5	GCG	35	
12	3	13	9	GCG	56	44
13	1	1	1	GOG	17	
13	2	6	6	GOG	53	
13	3	3	3	GOG	32	34
14	1	21	14	GCG	81	
14	2	2	2	GCG	20	
14	3	28	19	GCG	107	69
15	1	10	9	GCG	56	
15	2	15	11	GCG	66	
15	3	25	15	GCG	86	69
16	1	18	10	GCG	61	
16	2	16	14	GCG	81	

16	3	17	10	GCG	61	68
17	1	5	3	GCG	25	
17	2	10	6	GCG	41	
17	3	6	4	GCG	30	32
18	1	5	4	GCG	30	
18	2	1	1	GCG	15	
18	3	4	4	GCG	30	25
19	1	13	7	GCG	46	
19	2	2	2	GCG	20	
19	3	4	2	GCG	20	29
20	1	3	3	GCG	25	
20	2	11	6	GCG	41	
20	3	7	6	GOG	53	40
21	1	4	4	GOG	39	
21	2	3	3	GOG	32	
21	3	1	1	GOG	17	29
22	1	3	2	GOG	24	
22	2	0	0	GOG	10	
22	3	5	3	GOG	32	22
23	1	5	3	GOG	32	
23	2	3	2	GOG	24	
23	3	67	12	GOG	96	51
24	1	6	4	GCG	30	
24	2	3	3	GCG	25	
24	3	10	9	GCG	56	37
				MEAN	36	
					TOTAL	649

Figure 4 shows the density distribution and the average estimated density for each section. The range varied from 13 to 69 tortoises per square mile with a mean of 36 per square mile for the entire 18 square mile area. The mean was used as the center point for establishing four categories of density; 0 - 17, 18 - 35, 36 - 53, and 54 - 71. The highest density was three sections (14, 15, 16) near the center in the interior of the area while the lowest was in the northwest corner nearest Rogers Lake. The total estimated population for the entire 18 square mile Complex One Charlie study area is about 650 tortoises. This was calculated by summing the means for each section.

Figure 4. Predicted Desert Tortoise Density Distribution on Complex One Charlie Study Area



4.3. Observations of live tortoises and carcasses

A total of four live tortoises were observed on the Complex One Charlie study site. Three were adult males and one was an adult, but the sex could not be identified because it was deep in a burrow. The fact that so few live tortoises were seen is not surprising. Relative density transect methods are not designed to find live tortoises. Transects are walked during the inactive season and often during mid-day when temperatures were commonly in excess of 38ºC (100ºF). At these times, tortoises have retreated deep into burrows, out of site of even an observer using a mirror to reflect sunlight into the burrow.

A total of 18 desert tortoise carcasses were found on the study area (Table 4). Half of the carcasses (9) were old (> 4 years) and impossible to identify as to sex because they were disarticulated or only a few bone fragments were remaining. The distribution of time-since-death can give valuable insights into historic mortality rates of a population of desert tortoises. In particular, it can yield evidence of whether diseases such as Upper Respiratory Tract Disease (URTD) have caused abnormally inflated mortality rates.

The data set for Complex One Charlie is small but shows a normal distribution with relatively few deaths in the < 1 year category and a gradually increasing number as TSD increases. It is unlikely that URTD has had a significant effect on the desert tortoise population in this area. None of the four live tortoises showed symptoms of URTD.

Excessive raven predation is an increasingly common cause of death of small tortoises. Evidence of raven predation usually manifests itself as a small peck hole in the plastron or carapace of a small animal. No evidence of raven predation was observed on this project.

Table 4. Time-since-death distribution of carcasses found on 18-square mile Complex One Charlie study area, T8N;R9W; Los Angeles County, CA

	TIME SINCE DEATH				
SEX	< 1 YR	1 - 2 YRS	2 - 4 YRS	> 4 YRS	TOTALS
UNKNOWN	1		3	9	13
MALE			1	2	3
FEMALE			2		2
TOTALS	1	0	6	11	18

4.4. Human Impacts

Counts of human impacts ranged from 64 to 1009 items per section with a mean of 284. These are summarized in Table 5 and detailed in Appendix 4. A polygonic distribution of human impacts was not completed because they varied so widely. A correlation analysis between average estimated tortoise densities and total counts of human impacts showed no relationship between the two variables (r^2 = 0.04).

Table 5. Counts of human impacts by legal section found on 18-square mile Complex One Charlie study area, T8N;R9W; Los Angeles County, CA

SECTION	NUMBERS OF HUMAN IMPACTS IN ALL CATEGORIES
7	77
8	80
9	126
10	715
11	86
12	1009
13	810
14	301
15	123
16	131
17	64
18	151
19	278
20	222
21	196
22	146
23	176
24	427
TOTAL	5118
Mean	284.3
Minimum	64
Maximum	1009

5. DISCUSSION OF RESULTS

Usually, when calibration data are used to determine regression curves, the data from each calibration transect are correlated with the estimated population density within that quarter section. We averaged the sign counts for all of the transects and correlated that with the total estimated population density. The desert tortoise is experiencing high mortality rates. This is especially true in the western Mojave where all of the calibration plots used in this study are located. As a result, sign counts are down from previous years resulting in smaller sample sizes. To compensate for this, we used the average sign count for the entire plot.

Typically, calibration curves are force fit through the origin. We did not do this. Our curves intercept the ordinate axis at about 10 tortoises/square mile for both observers. This means that even if 0 sign was found, the regression would estimate a density of 10 tortoises. This may not be invalid. Presumably, with the relatively small sample size of a standard transect, there is some level of tortoise population density at which it becomes undetectable with a small sample. This is consistent with other researcher's reports that show that relative density transects are insensitive to low population densities (Turner, *et al.* 1982). If this is not true, the worst case in the use of our regression equations would be an overestimate of the population density by 10 tortoises/square mile, an insignificant amount.

The highest population density was found near the center of the study area. This is not surprising since this is the most remote area of the study site and has the lowest human accessibility. The estimated density for this area is not high by desert tortoise density standards. Areas with greater than 250 tortoises per square mile would be considered high (Luckenbach, 1982). In comparison, the "high" area of Complex One Charlie would be considered low to moderate given the possible range of desert tortoise density.

The lowest density area was found in the northwest corner of the study area (Figure 4). The lowest density area generally corresponded with the saltbush scrub plant community (Figure 2). This area consisted of very sandy soil that was not conducive to burrow construction. Lower densities have typically been reported in saltbush scrub than in creosote bush scrub plant communities (Berry and Turner, 1984).

Measures of relative density are dependent upon the assumption that a relationship exists between the frequency of tortoise sign observed on a transect and the abundance of tortoises in the area around the transect. Several factors influence the validity of this assumption. These include sensitivity to tortoise activity on a seasonal and year to year basis, soil characteristics, vegetative characteristics, weather conditions, and observer bias (Turner, *et al.* 1982; Berry and Nicholson 1984).

Other than conducting transects during the inactive tortoise season before winter rains reduce sign counts (approximately July - October) and using experienced observers, little can be done to control this variability. This work was done in July during the inactive season and both of the observers were experienced in relative density transect work. However, the density estimate can be regarded as only an approximation of actual tortoise population.

A relationship probably does exist between human impacts and tortoise distribution. Other researchers using more intensive methods have found such a relationship (Berry and Turner, 1984). Our method of counting human impacts in this survey samples only 2.5% of the habitat. This is probably not a large enough sample size. Furthermore, human impacts are not homogeneously distributed. If a large garbage pile is encountered on the transect, this may inflate the human impact counts inordinately. Also, the counts are not weighted. A single can counts the same as a dirt road. The latter has a significant impact on habitat while the former does not.

We have since modified human impact analysis methods so that over 8% of the habitat is sampled. While counts are still recorded, other data are collected to quantify the surface area of human impacts thereby weighting them proportionate to their relative impact on habitat. Unfortunately, this analysis requires a task independent of tortoise sign counts and was not completed on the Complex One Charlie study area.

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